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A PROPOSAL FOR IMPROVEMENT OF SUPPLY
SUPPORT FOR SHIP OVERHAULS
IN THE HELLENIC NAVY

by

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The Hellenic Navy currently conducts ship overhauls without adequate planning for supply support. As a consequence, many of the overhaul tasks cannot be completed in the time allowed for the overhaul. This thesis proposes a new supply support system consisting of an inventory model designed to provide the necessary spare and repair parts needed during a ship's overhaul and a demand forecasting method to support the model. A longer planning horizon is also proposed to insure on-time delivery of the appropriate material. A modification in the current supply support responsibility is then proposed as a last step towards implementing the new supply support system.

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A Proposal for Improvement of
Supply Support for Ship Overhauls
in the Hellenic Navy

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ABSTRACT

The Hellenic Navy currently conducts ship overhauls without adequate planning for supply support. As a consequence, many of the overhaul tasks cannot be completed in the time allowed for the overhaul. This thesis proposes a new supply support system consisting of an inventory model designed to provide the necessary spare and repair parts needed during a ship's overhaul and a demand forecasting method to support the model. A longer planning horizon is also proposed to insure on-time delivery of the appropriate material. A modification in the current supply support responsibility is then proposed as a last step towards implementing the new supply support system.

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ABBREVIATIONS

AEE	Requisition for work
AS	Fleet Headquarters
BOM	Bill of Material
DDMN	Hellenic Navy Logistics Command
DEE	Job Order
GEN	General Staff of the Navy
HDF	Historical Demand File
HNSN	Hellenic Navy Stock Number
KEFN	Supply Center Command
LIBOR	London Interbank Offering Rate
MEA	Average Annual Consumption
OHDF	Overhaul Historical Demand File
UAF	Units per Application File

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I. INTRODUCTION

A. OVERVIEW

Greece is a country with a long naval tradition. Over 70% of the Greek mainland is surrounded by sea. The Hellenic Navy has the responsibility for guarding the country's borders and securing the independence and wealth of the country.

The overhauls of the warships take place at the Hellenic Naval Shipyards which have the required technical resources. However, as far as the spare and repair parts are concerned, Greece does not have the capability for manufacturing the parts needed to sustain the ships. About (90%) of the materials and spare parts needed during an overhaul come from foreign sources. The latter is because of the following:

1. The rapid evolution of electronics and mechanical warfare equipment.
2. The competition among different manufacturers of ships and weapons systems which has resulted in the production of a great variety of equipment.

Thus Greece, in order to cover its national defense needs, must obtain maintenance parts from United States of America (USA) as well as from various European nations rather than local sources. This supply system depends on two important parameters, namely "searching time" and

transportation time". Searching time is defined as the time the Hellenic Navy spends in finding the supplies of the needed parts. This involves determining who can provide these materials at the lowest price and in the shortest time.

Transportation time is defined as the time needed to obtain the parts once the order is placed. This includes manufacturing the part or locating it in the warehouse and transporting it to the Hellenic Navy.

The cost of an overhaul depends on:

1. The repair cost,
2. The cost of the repair parts needed,
3. The ordering cost for each part,
4. The transportation cost for each part.

Additional costs are incurred when an incorrect or unsuitable spare part arrives at the shipyard or when a part is urgently needed but is not available from the Hellenic Navy's inventory. These costs involve the total cost for obtaining the correct part as well as the time "cost" for keeping ship, crew, drydock, etc. tied up.

B. PROBLEMS ASSOCIATED WITH THE SUPPLY SUPPORT FOR OVERHAUL

The main source of the problem is the poor forecasting system used to determine the type and quantity of spare parts needed for the ship being repaired. Using the existing forecasting system, ship's personnel have been able

to forecast only six percent (6%) of the actual items needed for an overhaul. The remaining needs, ninety-four percent (94%), have been obtained using the following two methods:

1. Quick collection procedure; for items which are stored in our warehouses.
2. Spot buy procedure; for items which are not in stock in our warehouses.

The percentage of demand filled by each method is shown in Figure 1.

A spot buy order is much more expensive than an ordinary one due to its urgent character. It has also been proven by Hellenic Navy sources that spot buying extends the overhaul time and sometimes results in the warship having to leave the shipyard before the completion of the repairs.

Viewing the forecasting problem from another direction, only twenty-three percent (23%) of the items requisitioned by the ship in anticipation of the overhaul are used. The requisition breakdown is shown in Figure 2.

The HN personnel who have the responsibility for supply support believe that the reasons for the forecasting problems are the following:

1. The lack of a standard PERT chart for the activities of an overhaul for each type of ship.
2. The lack of a Bill of Materials (BOM) for the main systems and their subsystems.
3. Past data concerning needs for spare parts for overhauls is ignored.

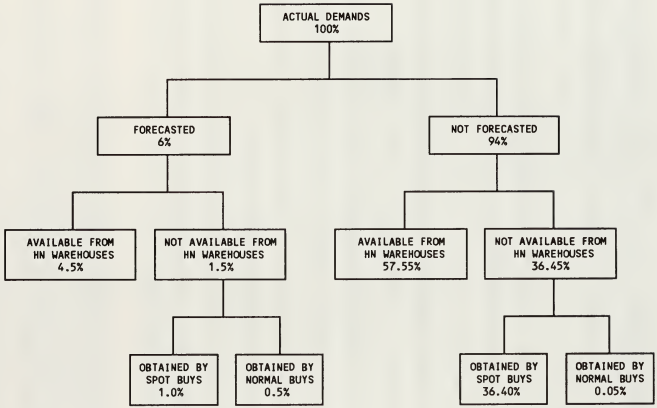


Figure 1. Forecasted and Not Forecasted Demands for Spare Parts During an Overhaul

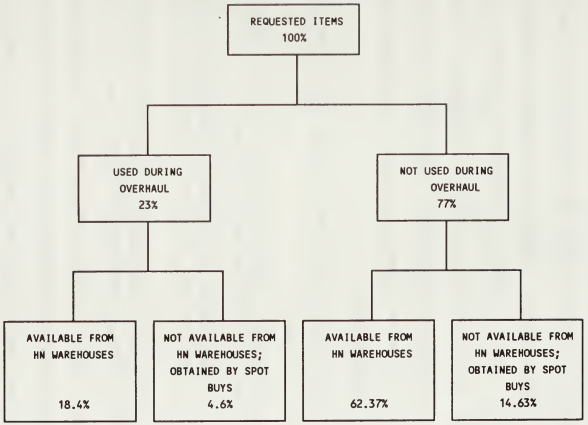


Figure 2. Breakdown of Actual Usage of Requested Spare Parts

4. The scheduling of the overhaul is done too late (within four months of the beginning of the overhaul).

5. The uncertainty in how long it takes to obtain the needed items.

The HN personnel who operate the ships and are responsible for the forecasts noted that after World War II and until the early 1970's most HN warships were ex-United States Navy (USN) ships. Usually a major overhaul was conducted in the USA by both the USN and HN personnel before the ships were turned over to the HN. However, 90% of the HN personnel did not have adequate knowledge of English in order to acquire the necessary skills for forecasting the ship's needs in spare parts.

This language barrier created several problems for the HN ship personnel, namely:

1. Unable to use past usage parameters; i.e., operating hours of various systems and equipment.

2. Unable to comprehend past data concerning overhauls and which repairs had been made when and to what extent.

3. Unable to conduct maintenance programs according to the manufacturer's recommendations.

Therefore, the HN personnel responsible for the overhaul were unable to use a comprehensive maintenance plan to forecast needs for spare parts and materials. Instead, they placed their requests for needed parts after inspecting each system and finding something faulty. Parts not available

were either ordered and installed later or the damaged ones were repaired.

However, since this inspection process was time-consuming, the ship's personnel tried to avoid it by copying the records of another ship of the same type and using them as a forecasting tool. Obviously such a forecasting method proved to be unreliable because the usage rates and maintenance performed in the past on identical equipment on two ships differed and consequently repair needs were not the same. Furthermore, all records were not properly kept and often the copying procedure was incomplete and incorrect creating additional data distortion. Finally, an evaluation of this forecasting method was not possible since data processing of requirements for spare parts was not available until the early 1970s.

For the last 20 years the HN has been building or buying warships mainly from European countries. However, the problem of incorrect forecasting of materials and spare parts persists since no attempt has been made to eliminate or modify the existing "copying" approach to forecasting described above. Thus, the situation today, as far as the forecasting of needs for these ships is concerned, is approximatively the same as during the period when the HN used ex-USN warships. Appendix A illustrates the problem by giving lists of comparative requests for an overhaul by two ships of the same type (Elli and Limnos) and shows which

items were requested by each ship and which were actually used by each ship. Note that the Elli was the initial ship to use the existing forecasting system.

Tables 1 and 2 concern limited and extended overhauls of several ships and indicate the number of items used out of those requested and also the number of items needed but not requested for each ship. The inaccuracies of the current forecasting system are obvious from these tables. Furthermore, Table 3 shows the budget burden resulting from this system because of the necessity of spot buys in order to offset poor forecasting.

The consequence of inaccurate forecasting is that in many cases only partial repair of a piece of machinery or weapon system can be accomplished, For example, instead of a planned complete overhaul of an engine, only a preventative maintenance can be performed.

C. THESIS OBJECTIVE

The objective of this thesis is to develop and propose a method which will facilitate the forecasting and the ordering of the "correct" spare parts well in advance so that the overhaul of a ship can be accomplished without delays.

SHIP NAME	NO. OF ITEMS REQUESTED BY THE SHIP	NO. USED OUT OF REQUESTED ITEMS	NO. OF ITEMS NOT REQUESTED	TOTAL NO. OF ITEMS USED
TOBAZIS	440	56	897	953
ARIS	38	4	257	261
DANIOLOS	1	1	531	532
KISSA	43	10	242	252
AIDON	30	--	12	12
ADIOPI	41	9	250	259
ESPEROS	36	1	79	80
TOTAL	629	81	2268	2349

TABLE 1. LIMITED* EXTENT OVERHAUL (90 DAYS PERIOD) FOR SEVEN SHIPS

* The duration of a limited extent overhaul does not exceed 90 days.

SHIP NAME	NO. OF ITEMS REQUESTED BY THE SHIP	NO. USED OUT OF REQUESTED ITEMS	NO. OF ITEMS NOT REQUESTED BUT NEEDED	TOTAL NO. OF ITEMS USED
ARIS	201	24	754	778
THEMISTOCLES	132	9	955	904
KRIEZIS	151	33	781	814
PAPANIKOLIS	230	38	313	351
LESVOS	119	1	210	211
AKTION	49	16	303	319
KISSA	103	27	254	281
AYRA	91	56	213	269
ATALANTI	69	29	202	231
ADIOPI	15	1	226	227
TOTAL	1160	234	4211	4445

TABLE 2. EXTENDED* OVERHAUL (180 DAYS PERIOD) FOR TEN SHIPS

* The duration of an extended overhaul may vary from 90 days to six months.

SHIP NAME	NO. OF NOT REQUESTED BUT USED ITEMS DURING THE OVERHAUL	NO. OF NOT REQUESTED BUT USED ITEMS AND AVAILABLE IN THE WAREHOUSE	NO. OF NOT REQUESTED BUT USED ITEMS AND SUPPLIED BY SPOT BUYS PROCEDURE	COST OF ITEM SUPPLIED BY SPOT BUYS PRO-CEDURES IN DRACHMAS
TOBAZIS	897	501	396	3,608,000
ARIS	257	143	114	1,904,000
DANIOLOS	531	311	220	3,100,000
KISSA	496	298	198	2,128,000
AIDON	12	4	8	66,000
ADIOPI	476	324	152	1,216,000
ESPEROS	79	66	13	159,000
ASPIS	754	501	253	2,441,000
THEMISTOCLES	955	550	405	4,313,000
KRIEZIS	781	487	294	1,190,000
PAPANIKOLIS	313	202	111	1,848,000
LESVOS	210	165	45	634,000
AKTION	303	140	163	2,403,000
AVRA	213	129	84	792,000
ATALANTI	202	139	63	618,000
TOTAL	6,479	3,960	2,512	43,420,000

TABLE 3. BUDGET BURDEN BECAUSE OF SPOT BUYS

D. PREVIEW OF CHAPTERS

Chapter II provides a description of the existing system. In this chapter emphasis is on the shipyard's overhaul schedule and the supply support method. Chapter III provides an analysis of the proposed forecasting and inventory stocking method. Chapter IV describes the steps for implementing the proposed method. Chapter V provides a summary of the thesis as well as conclusions and recommendations.

II. THE EXISTING SYSTEM

A. OVERVIEW

Two major commands of the HN have the authority and the responsibility for the planning and execution of a warship overhaul. They are:

1. The Fleet Headquarters (AS)
2. The Hellenic Navy Logistics Command (DDMN)

The main duty of the AS is the operational control of the warships. The General Staff of the AS sets the schedule for an overhaul for an individual ship based on:

1. Operational needs of the fleet.
2. The technical expertise of the personnel who serve in AS.
3. The daily report of a ship's condition provided by ship's personnel to the AS personnel.

A schedule is published on an annual basis. This contains an overhaul timetable for each of the ships including information as to the work to be done on the machinery and weapon systems and the estimated time required for the execution of the overhaul. The General Staff of the Navy (GEN), with the assistance of the AS and the DDMN, decides on the final form of the above schedule. The DDMN is then responsible for the execution of the overhaul schedule and keeping the AS informed of progress.

The Shipyard at the Naval Base where the ship is home-ported conducts the overhaul. The Naval Base coordinates the activities of the shipyard and the warehouse divisions and the Supply Center Command (KEFN), which is not located at the shipyard, ensures the availability of the materials and spare parts needs for the overhaul according to the orders placed by the ship. Figure 3 shows the information flow between the departments/commands.

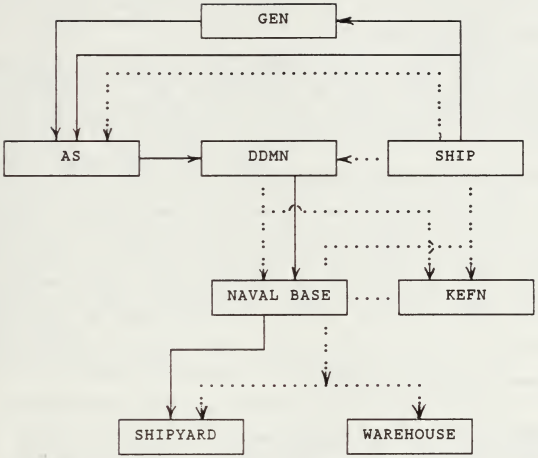
B. SHIPYARD OVERHAUL SCHEDULING.

Four months in advance of a ship's scheduled overhaul a meeting is held between the representatives of the ship, the shipyard, KEFN, and AS. This committee takes into consideration:

1. All the work suggested to be done during an overhaul by the manufacturer.
2. New repairs which are recommended by the ship's crew.
3. Repairs to be done by the ship's personnel.
4. Repairs to be done by the shipyard.
5. Repairs to be done at both levels combined.

An example of the fifth case is the repair of a piece of machinery or an equipment which has to be removed from a ship by its personnel so that it can be repaired by the shipyard.

The ship must provide the shipyard with the necessary work requisitions (AEE) which contain a detailed description



——————— Information flow for repairs to be done

..... Information flow for obtaining repairs parts

Figure 3. Information Flow Chart Between the Departments/Commands

of the required repairs for each equipment. This is done in the last stages of the planning for the overhaul and after the meeting between the representatives of the ship, shipyard, KEFN, and AS.

For each task to be performed during overhaul the shipyard issues an order for a job execution (DEE) to the relevant maintenance department. This order includes a detailed step-by-step description of the work that has to be done. The department has to perform the specified repairs within the time limit specified by the DEE. This limit assumes that no shortages in materials and spare parts will occur. The execution of work is monitored by the ship's personnel who are responsible for submitting detailed progress reports to the AS.

C. SUPPLY SUPPORT FOR OVERHAULS

At the same time as the ship submits its requisitions for work (AEE's) to the shipyard, the ship also submits a list containing an estimate of the spare parts required for each AEE, and a table is prepared containing the spare parts needed for the installation and units per application. This table is sent to the shipyard authorities and the KEFN no later than 10 days after the original work requisition was submitted. A survey is carried out by the shipyard departments to see what parts are on hand. For those which are not, an additional list is prepared and given to

the KEFN. Then the KEFN determines whether the materials on that list are available in the HN warehouses.

After the available materials are located, they are gathered and stored either in the storehouses of the shipyard or in other nearby warehouses. The KEFN is also responsible for the collection of all the spare parts stocked in the warehouses of the shipyard. The whole procedure takes about ten days.

Orders are placed for those items which are not available, or are available but in inadequate quantities. The orders are of high priority so that the schedule of the overhaul will not be delayed. Most of these orders result in spot buys.

The following procedures are computer aided:

1. Stock status of the materials and spare parts.
2. Status of orders already placed so that spot buys can be avoided. In the event that previous orders for same material are outstanding this program will give information as to quantities ordered and delivery dates.
3. The recording of materials and spare parts actually used by the maintenance departments and the ship during overhaul. (This program is still being developed).

D. ORDERING OF INVENTORY

1. Order Quantity

There is no special procedure for ordering the needed quantity for overhaul. In general, the order quantity for spare and repair parts is calculated on an

quantity for spare and repair parts is calculated on an annual basis using historical demand rates. For the special situation of overhauls the calculation may be more frequent, usually quarterly.

The forecast of annual demand uses data on actual annual demands from the last five years. The forecasting model is a weighted moving average. The demand of the most recent past year is multiplied by five. The demand of two years ago is multiplied by four, etc. The sum of the weighted five years of demands is then divided by 15, the sum of the multipliers of the five years. For example, suppose that we are at the end of 1988 and we wish to calculate a demand forecast for 1989 if the demands of the last five years are, respectively:

1. For 1988: 10 units,
2. For 1987: 14 units,
3. For 1986: 8 units,
4. For 1985: 16 units,
5 For 1984: 8 units.

The forecast for 1989 is calculated as follows:

$$\frac{10x5 + 14x4 + 8x3 + 16x2 + 8x1}{5 + 4 + 3 + 2 + 1} = \frac{170}{15} = 12 \text{ units.}$$

An order for 12 units is then placed when the stock level drops to a predetermined recorder point based on an estimate of procurement lead time and some degree of safety

or emergency stock. Procurement lead time is also forecast from historical values.

2. Budget Constraints

At the beginning of the year a credit line is established by the HN covering the annual expected costs of maintenance and overhaul, including materials. However, no allocation is made specifically for any type of ship or group of ships. The monitoring of the costs of materials supplied to all ships is carried out by the KEFN. In case of a budget overrun during the last quarter of the year necessary credit can be obtained from the next year's budget.

E. CURRENT ACTIONS TO SOLVE THE FORECASTING PROBLEMS

During last year the KEFN and shipyard authorities have undertaken the following actions to overcome the forecasting problems mentioned in Chapter I:

1. The KEFN is creating an Overhaul Historical Demand File (GHDF) which contains all the data about materials requested and used during overhaul for each ship.

2. After each overhaul a table is constructed for comparing the initial request and the actual needs. Examples of this type of table were Tables 1, 2, and 3.

3. With the assistance of AS the shipyard has started developing computerized PERT charts for each type of ship. These charts include all of the activities of the ship's overhaul in detail.

4. A file is being developed by the shipyard which contains only the actual needs in materials and spare parts for each activity on the PERT chart.

In order to cope with the need for rapid availability of non-stocked materials, especially for those continuously demanded, the KEFN and the shipyards have begun to search for Greek manufacturers who will be able to produce and supply the HN with spare parts needed for an overhaul. This may eliminate the large procurement lead time associated with purchases from foreign manufacturers. However, locally purchased items must have the same quality as their foreign equivalent.

III. PROPOSED INVENTORY STOCKING METHOD

A. OVERVIEW

An inventory model which can provide spare parts for an overhaul has been developed by McMasters [Ref. 1] and applied by Slaybaugh [Ref. 2]. This chapter describes that model. It also discusses the availability of data needed to use the model.

B. DEMAND DISTRIBUTION

A six-month overhaul schedule of n identical ships creates a total demand for a spare or repair part which is a random variable whose probability of assuming a certain value can be modeled using the binomial probability distribution. The probability p(x) of a total demand for x units of a given part during a six-month period can be expressed by: [Ref. 1].

$$p(x) = \frac{n!}{x!(n-x)!} P^x Q^{(n-x)}, \qquad (1)$$

where

P = Probability of a given part needing to be replaced during an overhaul.

Q = (1-P), the probability of the given part not needing to be replaced.

x = 0, 1, 2, ...n.

The mean and the variance of this distribution are nP and nPQ, respectively. If the units of application m are greater than one per ship, equation (1) can be easily modified to:

$$p(x) = \frac{nm!}{x!(nm-x)!} P^x Q^{(nm-x)}, \qquad (2)$$

where x = 0, 1, 2, ...,nm.

C. PROPOSED INVENTORY MODEL

When a probability of replacement is less than 100%, the amount of inventory to stock is not obvious. If n is stocked there is a good chance that a surplus will exist at the end of the six-months period after the scheduled overhaul is completed. If, on the other hand, a very small fraction of n is stocked, there is a good chance that the scheduled overhaul cannot be completed on time due to a shortage of repair parts. The optimum level to stock should be a balance between these two extremes.

A logical way in which to determine this balance is to consider the costs associated with shortages and surpluses. A surplus would be associated with money tied up in items which could have been spent on other parts for that six months or for the next. A shortage could result in work stoppage until the part could be located elsewhere in the supply system or purchased through a spot buy. In addition,

a delay in the availability of the overhauled ship to the fleet may occur.

A model which balances these costs is presented by McMasters [Ref. 1]. The model is a function of the following parameters:

1. Processing cost. If Cp is the cost per unit incurred in placing a repair part into shipyard warehouses, then the total cost of Y units is Cp times Y.

2. Holding cost. If Ch is the cost per unit held for six months then the total cost of Y units is Ch times Y if the cost is assumed to be incurred regardless of the length of time the item is in storage during the six months period. This assumption is reasonable since the storage space needed must be large enough to hold the entire quantity Y of a repair part for some part of the six months period.

3. Shortage cost. The shortage cost is representative of the cost of the time delays associated with submitting a requisition to the KEFN when the shipyard experiences a stockout. If Cs represents the shortage cost per unit and the demand x for repair part during the six-month period exceeds the inventory level Y in the shipyard warehouses, then the shortage cost will be Cs(x-Y). This cost consists of many elements but mostly represents labor cost.

4. Surplus cost. The unit cost of a surplus can be considered to be the product of the unit purchase cost "C" of a repair part and a risk factor "K". The value of "K" can range from zero to infinity. The risk factor should be minimal if the near future production schedules are expected to absorb any excess stock. The surplus cost will be incurred when the demand x is less than Y and is the product KC(Y-x).

The expected total costs over a six-month period associated with stocking a quantity Y of a given repair part

is the sum of the costs listed above weighted by the probability p(x) that x will be demanded during the six-month period. It is described mathematically by equation (3).

$$EC(Y) = (Cp+Ch)Y + \sum_{x=0}^{Y} KC(Y-x)p(x) + \sum_{x=Y+1}^{n} Cs(x-Y)p(x), \quad (3)$$

where p(x) is given by equation (1) or (2).

D. OPTIMAL INVENTORY LEVEL

The optimal order quantity of a specific repair part minimizes the expected total costs EC(Y). From the calculus of finite differences the optimal inventory level Y is the largest value of Y for which:

$$\bar{P}(Y) > \frac{Cp+Ch+KC}{Cs+KC} = R \quad (4)$$

where $\bar{P}(Y) = \sum_{x=Y}^{n} p(x)$ and R is the optimal probability of stockout; that is, the expected total costs are minimized when a probability (risk) of stockout of R is allowed.

Determination of the optimal order quantity (Y) is illustrated by the following example. Assume that the item with stock code 88805 has the following parameters:

C	= \$16	K	= 0.42
Cp	= \$ 0.48	n	= 22
Ch	= \$ 0.8	m	= 4
Cs	= \$24	P	= 0.225

First we compute the value of R

$$R = \frac{Cp+Ch+KC}{Cs+KC} = \frac{0.48+0.8+(0.42x16)}{24+(0.42x16)} = \frac{8.00}{30.72} = 0.2604$$

Next, $p(x) = \frac{88!}{x!(88-x)!} (0.225)^x (0.775)^{88-x}$

$$= \frac{88!(0.775)^{88}}{x!(88-x)!} (0.29)^x$$

and x = 0, 1, 2, 3, ..., 88.

To solve the problem we need to compute

$$\bar{P}(Y) = \sum_{x=Y}^{88} p(x)$$

for several values of Y. First, we realize that

$$\bar{P}(Y) = 1-P(Y-1) = 1 - \sum_{x=0}^{Y-1} p(x).$$

Next we can make use of the following recursion equation for computing p(x).

$$p(x) = Q^n \quad \text{for } x = 0;$$

$$p(x) = \frac{(n - (x - 1))P}{x\,Q} \quad p(x - 1) \quad \text{for } 0 < x \leq n.$$

Table 4 provides the details of the computation needed to determine the optimal quantity Y. These computation were made using the LOTUS 1-2-3 electronic spreadsheet program. It can be seen that 0.2604 is between Y values of 21 and 22 units. Therefore, the optimal quantity Y is equal to 21 since it is the largest value of Y for each P(Y) > R. We note that Y exceeds the expected demand (nmP) of 19.8.

E. ESTIMATING THE PROBABILITY OF REPLACEMENT

The probability of replacement (P) values can be estimated as follows [Ref. 2].

$$\hat{P} = \frac{D}{(UA).(N).L} \tag{6}$$

CODE	88805	Y	$P(\bar{Y})$
Probability,P	0.225	0	1.0000
		1	1.0000
C ($)	16	2	1.0000
		3	1.0000
K	0.4	4	1.0000
		5	1.0000
Ch ($)	0.8	6	0.9999
		7	0.9997
Cs ($)	24	8	0.9991
		9	0.9976
Cp ($)	0.48	10	0.9941
		11	0.9870
R	0.261	12	0.9736
		13	0.9509
nm	88	14	0.9157
		15	0.8652
		16	0.7983
		17	0.7161
		18	0.6219
		19	0.5211
		20	0.4202
		21*	0.3254*
		22	0.2415
		23	0.1717
		24	0.1167
		25	0.0759
		26	0.0472
		27	0.0280
		28	0.0159
		29	0.0086
		30	0.0045

TABLE 4. TABLE OF $\bar{P}(Y)$ FOR THE EXAMPLE

where:

$\hat{P}$ is an estimate of P;

D is the total demand over a specified number of years;

UA is the units of application for each installation in a ship;

L is the number of identical ships overhauled during the same specified number of years used for D; and

N is the number of installations per ship.

The data needed can be obtained from the Overhaul Historical Demand File (OHDF) and the Units per Application File (UAF) of the KEFN.

In Appendices B and C, P values are shown for selected items which belong in the Main Engine and the Electric Motor for the Fast Patrol Ships of the HN. Data spanning ten "six-month" time periods (5 years) were used to provide as large a sample size as possible and hence reduce the standard error of the estimate.

The columns in these appendices are:

1. The six-digit Hellenic Navy Stock Number (HNSN),
2. The number of spare parts used during the last five years for each overhaul, by six-month intervals,
3. The total number of spare parts actually used during the last five years,
4. The total number of parts subject to replacement on ships already overhauled in the past five years, and
5. The probability of replacement.

F. COST PARAMETERS ANALYSIS - DISCUSSION

In the search for values for the cost parameters we discovered that they had already been determined by P. Vectis [Ref. 3], but had never been used due to lack of an appropriate inventory model.

The processing cost (Cp) is calculated as 3% of the purchase price and includes ordering and transportation costs. The holding cost (Ch) is calculated as 10% of the purchase price annually or 5% for a six-month period. On an annual basis it is the sum of the approximately 6.5% London Interbank offering rate (LIBOR) plus a 3.5% spread. This spread includes bank profit over LIBOR and costs associated with warehousing.

The shortage cost (Cs) is calculated as the product of 3/2 Cp, "a", and the unit purchase cost (C); 3/2 (Cp.a.C), where 3/2 or 1.5 is used for a six-month interval and "a" is a factor ranging from 10 to 100 depending on the lead time of the item and the ship's duties. In the overhaul case the factor "a" has values from 50 to 70 depending on where the equipment being repaired lies on the PERT diagram. If the spare part is used in a repair that lies on the critical path then "a" has a value of 70; otherwise it has a value of 50. In our computations the shortage cost formula will be 1.5 Cp·50·C for a six-month interval.

The surplus cost (KC) has the risk factor "K" calculated as $\frac{1-P}{P}\beta$ where $\frac{1-P}{P}$ indicates how many time the probability of non-occurrence exceeds the probability of occurrence and "β" is a correcting factor. Beta (β) may have the following values: 0.1 when the material may be used again within 3 years, 1.0 when the material may be used again but beyond 3 years and within 10 years from now, and 100 when the material may be used again after at least 11 years. This indicator can be determined only by obtaining historical demand data for each item from the OHDF and HDF. In our computations in Appendices D and E the β value is 0.1 since we assume that the materials are used again within 3 years.

Appendices D and E present the values of the optimal risk R and stockage level Y for all materials in appendices B and C. Appendices D and E also present:

1. HNSN.
2. Unit purchase cost (C).
3. Unit surplus cost (KC).
4. Unit holding cost (Ch).
5. Unit shortage cost (Cs).
6. Unit processing cost (Cp).

The binomial parameters nm and P used to compute optimal Y are contained in the last two columns of Appendices B and C.

For items having very large nm values, a Normal approximation was used to compute Y. The formula is

$$Y = nmP + z\sqrt{nmPQ}\ , \qquad (7)$$

where z is the tabled Normal deviate corresponding to a risk of R.

IV. IMPLEMENTATION OF THE PROPOSED MODEL

A. OVERVIEW

In the previous chapters we discussed the existing method for stocking for supply support for ship overhaul and considered an alternative stocking method based on the mathematical model developed by McMasters [Ref. 1]. The data needed for this proposed method is readily available from the following sources:

1. PERT chart of the ship's overhaul,
2. Bill of material (BOM),
3. Overhaul Historical Demand File (OHDF),
4. Historical Demand File (HDF),
5. Stock Status, and
6. Control of orders placement.

This alternative method can be successfully implemented by changing the existing decision process in the following way:

1. Transfer responsibilities from the ship to the KEFN for the prediction of needed materials for an overhaul.
2. Increase the length of the planning horizon for an overhaul.

3. Modify the proposed decision process based on:

   - PERT Charts,
   - BOM,
   - OHDF,
   - HDF,
   - Mathematical model,
   - Stock status,
   - Control of orders placement.

4. Monitor and control the variances between prediction and actual needs.

The following section present the details of these four steps.

B. TRANSFERRING OF RESPONSIBILITIES FROM THE SHIP TO THE KEFN

Past data examination demonstrates beyond any doubt that ship's personnel cannot predict the needs in spare parts for an overhaul because they do not have an adequate database. On the other hand, these predictions can be easily made by KEFN using the estimating procedure described in Section E of Chapter III.

C. INCREASING THE PLANNING HORIZON FOR THE OVERHAUL

As the majority of the spare parts are supplied from foreign countries we have to allow for possible long lead times for delivery. The planning horizon should therefore be two years ahead instead of four months as is done now. This two-year period is proposed because some spare and repair

parts have lead times well in excess of 12 months. In addition, it is sometimes difficult to find spare parts from the original manufacturers because the majority of the ships are rather old. Therefore, in those cases when certain spare parts are no longer manufactured, special requests are made to the manufacturer to re-make these spare parts at additional cost. If this is not possible, then attempts are made to obtain those parts from other shipyards. Finally, if that fails we try to either change the system requiring the part or give up trying to fix it.

D. DECISION PROCESS

The decision process is diagrammed in Figure 4. Its goal is for the KEFN to place material orders early enough so that the needed material will be available on time. The KEFN should organize the procurement schedule based on:

1. The standard PERT diagram of the overhaul. The PERT diagram will provide information about the needed repairs in the early stages of the planning of the overhaul. It will provide information about the timing of these repairs, so that the KEFN will be able to place its orders well in advance.

2. The Bill of Materials for each operation described in the PERT diagram. The KEFN gets this information from the manufacturers of weapon systems.

3. Past usage of materials described by the historical files, OHDF and HDF.

4. The inventory levels determined from the proposed mathematical model.

5. The current stock status including control of order placement.

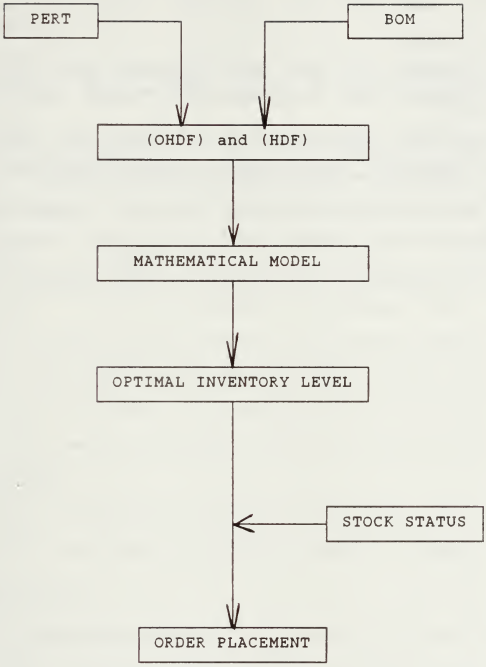


Figure 4. Decision Process Flow Diagram

E. FEEDBACK AND CONTROL

After each overhaul the KEFN should perform the following tasks:

1. Collection of all data connected with actual material usage so that the OHDF and HDF files are updated.

2. Exhaustive examination of any deviations between forecasted and actual needs. This process will help the KEFN establish reliable model parameters.

As experience with the model is gained, changes may be appropriate. These may be merely changes in parameter values or they may be the addition of cost elements to the model.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The HN faces the problem of accurate forecasting of materials and spare parts needed for the overhaul of its ships. Under the present forecasting system only 6% of the items needed are successfully forecasted. Chapters I and II described the way the existing forecasting system functions.

A proposed forecasting and inventory stocking model, developed at the Naval Postgraduate School by Professor McMasters is then reviewed in Chapter III. This inventory model provides both a forecasting methodology based on the overhaul bill of materials and the means for determining the amount of inventory to stock which will balance the costs associated with the inventory shortages and surpluses.

Chapter IV describes the steps which should be followed by the HN to implement the model presented in Chapter III.

B. CONCLUSIONS

The recommended changes to the HN material support system for shipyard overhaul will help provide better supply support because:

1. Forecasts will be based on relevant data.
2. The stockage model will attempt to balance costs and benefits.

3. Part of the responsibility for materials forecasting will be transferred from the ship's personnel to the KEFN which has the computerized data base needed for forecasts.

4. Because PERT will be used for planning lead times, materials which are important for the on-time completion of the overhaul should become more available.

C. RECOMMENDATIONS

In order for the above proposed system to be implemented and operate smoothly, the following major recommendations are made.

1. An accurate data system must be developed to provide information from past overhauls, present inventory, and all other related data.

2. There needs to be a change in attitude and thinking by ship personnel to allow overhaul forecasting by the KEFN. The KEFN, as a command, must also accept this new role and responsibility and coordinate all aspects of overhaul forecasting.

3. A special team should be created to oversee the functioning of the overhaul forecasting system. They are to evaluate the utilization of the spare parts, identify specific problems producing failure of parts and propose solutions for each. Such a team would require constant interaction and flow of information between the KEFN and the shipyard. This interaction should be carefully structured and monitored to allow for a smooth information exchange with minimum error. The personnel involved in the team activities must work full-time in their positions. There should also be reserve servicemen and civilians with relevant knowledge and experience to serve as back-up. As can be seen, the role of this team would be multifunctional.

APPENDIX A
COMPARATIVE FIGURES OF "COPYING" FORECASTING SYSTEM

CODE NUMBER OR HNSN	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
0000-NT-P289162	*				
0000-NT-P295273	*				
0000-NT-P901037	*	*			
0000-NT-P901038	*	*			
0000-NT-P901039		*			
0000-NT-P901043	*	*			
0000-NT-P901044	*	*			
0000-NT-P901045	*	*	*	*	*
0000-NT-P901046	*	*			
0000-NT-P901047	*	*			
0000-NT-P901048		*			
0000-NT-P901049	*	*			
0000-NT-P901051	*	*	*	*	*
0000-NT-P901052	*	*			
0000-NT-P901053	*				
0000-NT-P901054	*		*		
0000-NT-P901055		*			
0000-NT-P901056	*				
0000-NT-P901057	*				
0000-NT-P901252		*			
1075-NT-AA12922	*	*			
1095-00-3342409	*		*		
1285-01-0268364	*	*			
1285-01-0268369	*	*			
1430-00-0885464	*		*		
1630-01-0497547	*	*			
1630-01-0497661	*	*	*	*	*
1650-99-7182131	*	*			
2010-17-9020508	*	*			
2010-17-9020509	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
2010-17-9020510	*	*			
2010-99-5265475	*				
2010-99-5466859		*	*		
2010-99-5466866	*				
2010-99-5466869	*	*			
2010-99-5466871		*			
2010-99-5466872	*		*		
2010-99-5466873	*				
2010-99-5466876		*			
2010-99-5466878	*	*			
2010-99-7200212	*	*		*	
2040-00-8154791	*				
2540-17-9050788		*			
2540-17-9050789	*				
2815-17-0443854		*			
2815-17-9021610	*	*			
2910-12-1747733	*	*	*		
2910-14-3485687	*				
2910-14-3485702	*	*			
2910-17-0443982		*			
2910-17-0444029	*	*		*	
2910-99-5241798	*				
2910-99-5242369	*	*			
2910-99-5290031	*				
2910-99-5344309		*			
2940-99-5244033	*	*			
2940-99-5244105	*	*			
2940-99-5411090	*	*			
2940-99-5442847	*	*			
2940-99-7191862	*				
2990-00-4432086	*	*			
3010-17-0492906	*	*	*	*	*

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
3010-17-0492907	*	*			
3020-17-0443649		*			
3020-17-9017733	*				
3020-99-7190426		*			
3030-00-0124801	*	*		*	
3030-12-1371685		*			
3030-12-1672785	*	*			
3030-17-0068148					
3030-17-0250864	*	*			
3030-17-0333505	*	*			
3030-17-0490890	*				
3030-17-7035512	*	*	*		
3030-17-7035586	*	*			
3030-17-7035603					
3030-17-7035617	*	*	*	*	*
3030-17-7035648	*	*	*	*	*
3030-99-5474657	*				
3030-99-5474660	*	*			
3040-00-9198743		*			
3040-17-0400779	*				
3040-17-0400780	*	*			
3110-00-1002361	*	*			
3110-00-1014580	*				
3110-00-1014609	*	*		*	
3110-00-1091123	*				
3110-00-1091155	*	*			
3110-00-1367777	*	*			
3110-00-1428486					
3110-00-1428508	*	*			
3110-00-1428594	*	*			
3110-00-1428622	*	*			
3110-00-1428671	*				

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
3110-00-1448993	*	*			
3110-00-1556167	*	*			
3110-00-1556190	*	*			
3110-00-1556198	*	*			
3110-00-1556230	*	*			
3110-00-1556238	*	*	*	*	*
3110-00-1556324	*	*			
3110-00-1556727	*	*	*	*	*
3110-00-1557351	*		*		
3110-00-1559628		*			
3110-00-1561422	*	*			
3110-00-1563548	*	*		*	
3110-00-1564086		*			
3110-00-2938266	*	*			
3110-00-2938644	*				
3110-00-2939163		*			
3110-00-2939302	*	*			
3110-00-5405199	*	*	*		
3110-00-5543241	*	*			
3110-00-5543277	*				
3110-00-55433355	*	*			
3110-00-5543468	*	*		*	
3110-00-5545314		*			
3110-00-5545324	*				
3110-00-5545399	*				
3110-00-5545412	*	*			
3110-00-7262407	*	*	*	*	*
3110-00-7319145	*				
3110-00-9250400	*	*			
3110-00-9894874		*			
3110-12-1458995	*	*			
3110-12-1578483	*	*		*	

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
3110-12-1873540	*				
3110-17-0441561					
3110-17-0441578	*				
3110-17-0447159	*				
3110-17-0447160		*			
3110-17-6084119	*	*			
3110-99-9500751	*				
3120-00-1204892		*			
3120-14-3485691	*	*			
3120-17-0400771	*	*			
3120-17-0437018	*	*			
3120-17-0467406	*	*			
3120-17-0494218	*	*			
3120-17-6014245	*	*			
3120-17-6014246	*	*			
3120-99-5304108		*			
3130-00-8493239		*			
3439-NT-AA-00243		*			
3439-NT-AA33485	*				
3439-NT-AA33486	*				
3439-NT-AA45938	*	*			
3439-NT-AA58605	*	*		*	
3439-00-1059945	*				
3439-00-1848953	*	*			
3439-00-2528352	*				
3439-00-2554566	*	*	*		
3439-00-2622653	*	*			
3439-00-2733722	*				
3439-00-4331919	*	*		*	
3439-00-5408998	*				
3439-00-8782153	*	*			
3439-00-8782882	*				

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
3655-00-7681585	*	*			
4010-MT-AA25062	*	*			
4010-00-1849558	*	*			
4010-00-5422405	*				
4020-00-5607732	*	*			
4030-00-2699771	*	*			
4030-00-2824885	*	*			
4130-00-0363912	*	*			
4130-00-1204890	*	*	*	*	*
4130-00-1330970	*	*			
4130-00-1420605	*	*	*	*	*
4130-00-3743042	*				
4130-00-3918992	*	*			
4130-00-4432087	*	*			
4130-00-4548118	*				
4130-00-4602624		*			
4130-00-4602625		*			
4130-00-4692318		*			
4130-00-4955995		*			
4130-00-7356978	*				
4130-00-7591938	*				
4130-00-7618607		*			
4130-00-7618612	*	*	*	*	*
4130-00-7677201	*	*		*	
4130-00-7687222	*				
4130-00-8765394					
4130-00-8767249	*				
4130-00-8767257	*		*		
4130-00-8767259	*	*			
4130-00-9692090	*	*			
4130-12-1408532	*	*			
4130-12-1594156	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
4130-17-0353968	*	*	*	*	*
4130-17-6014256	*	*			
4130-17-7080956	*	*			
4140-00-8167049	*	*			
4140-14-0403870	*	*			
4140-14-0518951	*				
4140-14-3460577	*	*			
4140-17-0442908	*	*		*	
4140-17-0476290	*				
4140-17-9037213	*	*			
4140-99-9432429	*	*	*	*	*
4210-17-0436698	*				
4240-00-2405141	*	*			
4310-00-6608766	*	*			
4310-01-0251851	*	*	*		
4310-01-0251855					
4310-01-0251856					
4310-01-0251861					
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4310-17-0347624	*	*	*	*	*
4310-17-0417912	*	*		*	
4310-99-5283831	*				
4310-99-5283854	*	*			
4310-99-5283855					
4310-99-5283868					
4310-99-5283869	*	*	*	*	*
4310-99-5283879	*	*			
4310-99-5283880					
4310-99-5283893					
4310-99-5283900					
4310-99-5283905	*	*			
4310-99-5283901	*				

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
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4310-99-5283908	*				
4310-99-5283910	*	*			
4310-99-5283913	*	*			
4310-99-5309398	*	*			
4310-99-5321250	*	*			
4310-99-6241699	*	*			
4310-99-7164955	*	*			
4310-99-7164956	*	*			
4320-00-8765392	*	*			
4320-12-1753047	*	*			
4320-12-1771743	*	*			
4320-14-3751552	*				
4320-14-3751553	*	*			
4320-14-3751554		*		*	
4320-17-0234962	*	*			
4320-17-0400777		*			
4320-17-0423839	*	*			
4320-17-0423849	*				
4320-17-0423854	*	*	*	*	*
4320-17-0423873	*				
4320-17-0423875	*	*			
4320-17-0424016		*			
4320-17-0424131	*	*			
4320-17-0424161	*	*			
4320-17-0424165	*		*		
4320-17-0427107	*				
4320-17-0438659		*			
4320-17-0442570	*	*			
4320-17-0442576	*	*			
4320-17-0442583	*				
4320-17-0451503	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
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4320-17-0465867	*	*	*	*	*
4320-17-0465868	*	*			
4320-17-0467021	*	*			
4320-17-0489538		*			
4320-17-0492904	*				
4320-17-0492908	*	*			
4330-01-0482685	*	*			
4330-17-0423756	*				
4330-17-0427314	*				
4330-17-0448154	*	*			
4330-17-0457755	*	*	*	*	*
4330-17-0493526	*	*			
4330-17-0495701	*				
4330-17-0506417		*			
4410-17-0447102		*			
4410-17-0447103		*			
4410-17-0447104	*				
4410-99-5248104	*	*	*	*	*
4410-99-5281639	*				
4410-99-5424706	*	*			
4410-99-5543771	*				
4410-99-5544568	*	*			
4440-01-0551917	*		*		
4440-17-0309585		*			
4540-17-0520982	*	*			
4610-00-1391494	*	*	*	*	*
4610-01-0324669	*		*		
4710-NT-AA62542	*	*			
4710-00-2774040	*		*		
4710-00-2774532		*			
4710-00-2774533	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
4710-00-2776131	*				
4710-00-2785353	*	*			
4710-00-2787859	*				
4710-00-2897994	*	*			
4710-00-2898004		*			
4710-00-2898005	*				
4710-00-5422468		*			
4710-00-6047942	*		*		
4710-00-8293036		*			
4720-NT-AA4704	*				
4720-17-0466794	*	*	*	*	*
4720-99-5241903	*				
4730-00-1892638	*	*			
4730-00-1892737	*	*		*	
4730-00-1961509	*	*			
4730-00-2493959	*	*			
4730-00-2656909	*		*		
4730-01-0251847		*			
4730-17-0456664	*				
4730-17-0456665		*		*	
4810-17-0467199	*				
4810-17-0483054		*			
4820-00-0361545	*	*			
4820-00-0361659	*	*			
4820-00-2169074	*	*			
4820-00-4709908	*	*			
4820-00-6156762	*				
4820-00-6309271	*	*			
4820-00-6702485	*				
4820-00-9131330	*	*			
4820-12-1821722	*				
4820-17-0417949	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON
4820-17-0420789		*			
4820-17-0442163	*	*			
4820-17-0447270		*			
4820-17-0448224	*	*			
4820-17-0450674	*	*		*	
4820-17-0450684	*				
4820-17-0450689	*	*			
4820-17-0457708	*	*			
4820-17-0470612	*	*			
4820-17-0485864	*	*			
4820-17-0485868	*	*			
4820-17-9041972	*	*			
4820-17-9041974	*				
4820-17-9041975	*	*			
4820-17-9041976	*	*			
4820-17-9042186	*	*	*	*	*
4820-17-9042187	*	*			
4820-17-9042190	*	*			
4820-17-9042191	*				
4820-17-9042192		*			
4820-17-9042193	*				
4820-99-5248276	*	*			
4820-99-5281616	*	*			
4820-99-5281641	*				
4820-99-5283859		*			
4820-99-5283860	*				
4820-99-5283872	*				
4820-99-5305882		*			
4820-99-5420004	*				
4820-99-7167888		*			
4820-99-7167890	*				

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
4820-99-7167986		*			
4820-99-7167987	*		*		
4820-99-7168054		*			
4820-99-7168095	*	*			
4820-99-7168558	*	*			
4820-99-7168559	*	*			
4820-99-7190606	*	*			
4820-99-9232516	*	*	*	*	*
4930-00-2532478	*	*	*	*	*
4935-99-9155940	*				
5110-00-2034731		*			
5110-00-2034948	*	*	*	*	*
5110-00-2339712	*				
5110-00-2346524	*	*			
5110-00-2346534	*	*			
5110-00-2346537	*	*			
5110-00-2346554	*				
5110-00-2346569	*				
5110-00-2397556		*			
5110-00-2425384	*				
5110-00-2492848		*		*	
5110-00-2492858	*	*			
5110-00-2774590	*	*			
5110-00-2774591	*	*			
5133-00-2279647	*	*			
5133-00-2279648	*	*			
5133-00-2279650	*	*			
5133-00-2279651	*	*			
5133-00-2279652	*	*			
5133-00-2279653	*	*	*	*	*
5133-00-2279654	*				
5133-00-2439612	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
5133-00-2669234	*				
5210-00-2211919	*	*			
5210-00-2432933	*	*			
5210-00-5402973	*	*			
5305-NT-AA60538	*				
5305-NT-AA60651	*	*			
5305-NT-AA60839	*	*			
5305-NT-AA60866	*	*			
5305-NT-AA60886	*	*		*	
5305-NT-AA61605	*	*			
5305-NT-AA61694	*				
5305-NT-AA61709	*	*			
5305-NT-AA62724	*	*			
5305-NT-AA62842	*	*			
5305-NT-AA63845	*			*	
5305-NT-AA64338	*				
5305-NT-AA64339	*	*			
5305-NT-AA64428	*				
5305-NT-AA64437	*	*			
5305-NT-AA64455	*	*			
5305-NT-AA64481	*				
5305-NT-AA64482	*	*	*	*	*
5305-NT-AA64484	*	*	*	*	*
5305-00-0149301	*	*			
5305-00-0510827	*	*			
5305-00-1744056	*	*			
5305-00-1744057	*	*			
5305-00-2253839	*	*			
5305-00-2269205		*		*	
5305-00-2269207					
5305-00-2269209		*			
5305-00-2269218	*		*		

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5305-00-2693211		*			
5305-00-5503934	*		*		
5305-00-7168128					
5305-00-7246760					
5305-00-8546690					
5305-00-9789381					
5305-00-9789395					
5306-00-2270916	*	*	*	*	*
5306-00-2270944	*	*			
5306-17-0505771	*	*			
5307-00-2487882					
5310-NT-AA60670					
5310-NT-AA60898					
5310-NT-AA60900					
5310-NT-AA60917					
5310-NT-AA61813					
5310-NT-AA61912					
5310-NT-AA62314					
5310-NT-AA62458	*	*	*	*	*
5310-NT-AA62653	*	*			
5310-NT-AA62654	*	*			
5310-NT-AA62656	*	*			
5310-NT-AA62718	*				
5310-NT-AA64483	*	*			
5310-NT-AA64489	*				
5310-NT-AA64490	*	*		*	
5310-NT-AA64714	*	*			
5310-00-0502261	*				
5310-00-2057840	*	*			
5310-00-2725697	*	*			
5310-00-2725701	*	*			
5310-00-2725702	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5310-00-6373631	*	*	*	*	*
5310-00-7320558	*	*			
5310-00-7616882	*	*			
5310-00-8767258	*	*			
5310-12-1694290	*				
5310-12-1889677	*	*			
5310-99-5322572	*	*			
5315-00-1879384	*	*	*	*	*
5315-00-1879449	*	*			
5315-00-2004545	*	*	*	*	*
5315-00-2341630	*	*			
5315-00-2981499	*	*			
5320-00-2341300	*	*			
5330-NT-AA00407		*		*	
5330-NT-AA00409	*				
5330-NT-AA00410	*	*			
5330-NT-AA00411	*	*			
5330-NT-AA74110	*	*			
5330-NT-AA74111	*	*			
5330-NT-AA74113	*	*			
5330-NT-P922006	*				
5330-NT-P922008	*	*	*	*	*
5330-NT-P922009					
5330-NT-P922010					
5330-NT-P922136					
5330-00-0203196	*	*			
5330-00-0203197	*	*			
5330-00-0203200	*	*	*	*	*
5330-00-1548328	*	*	*	*	*
5330-00-1784709	*	*			
5330-00-1790050	*	*	*	*	*
5330-00-1790052	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5330-00-1790053	*				
5330-00-1790054	*				
5330-00-1909978	*				
5330-00-2169080	*				
5330-00-2222566	*				
5330-00-2222569	*	*			
5330-00-2240868					
5330-00-2249276					
5330-00-2392865					
5330-00-2392868	*	*			
5330-00-2689880	*	*			
5330-00-2689882	*	*			
5330-00-2911528	*	*			
5330-00-5765229	*	*			
5330-00-5859500	*	*			
5330-00-5859501	*	*			
5330-00-5859502					
5330-00-6183222					
5330-00-6845098	*	*		*	
5330-00-8063197	*	*			
5330-00-8555719	*	*			
5330-00-8767233	*	*		*	
5330-00-9424727	*	*			
5330-00-9424728	*	*			
5330-12-1645907	*	*			
5330-14-3301811	*	*			
5330-14-3706378	*	*	*	*	*
5330-17-0023166	*	*			
5330-17-0226231	*	*			
5330-17-0234968	*	*			
5330-17-0292118	*	*			
5330-17-0417948	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
5330-17-0423846	*				
5330-17-0429939	*	*	*	*	*
5330-17-0439142		*			
5330-17-0442049	*	*			
5330-17-0442580	*	*	*	*	*
5330-17-0443860	*	*			
5330-17-0443987					
5330-17-0447142	*				
5330-17-0447144					
5330-17-0447947	*	*			
5330-17-0451507					
5330-17-0451509	*	*			
5330-17-0451849					
5330-17-0458116	*	*			
5330-17-0507475					
5330-17-6033651	*	*			
5330-17-6093760	*				
5330-17-6173285		*			
5330-17-6211563	*				
5330-17-7047246	*	*			
5330-17-7047310	*				
5330-17-7047434		*			
5330-17-7047447	*	*			
5330-17-7047496	*	*			
5330-17-7047586	*	*			
5330-17-7048504	*	*			
5330-17-7080366	*	*			
5330-17-7080368	*	*			
5330-17-7082244	*	*			
5330-17-7096545		*			
5330-17-9008179	*	*			
5330-17-9029107	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5330-99-4292519	*	*	*	*	*
5330-99-5228903	*	*	*	*	*
5330-99-5246751	*	*			
5330-99-5266116	*				
5330-99-5281920	*	*			
5330-99-5283918	*				
5330-99-5283920	*	*			
5330-99-5283921	*	*			
5330-99-5283929	*	*			
5330-99-5283932		*			
5330-99-5334538	*	*			
5330-99-5344973	*				
5330-99-5442849	*				
5330-99-5466874	*				
5330-99-5466875	*				
5330-99-6183072	*	*			
5330-99-7103505	*	*			
5330-99-7163936	*				
5330-99-7167842	*	*	*	*	*
5330-99-7167844	*	*	*	*	*
5330-99-7181039					
5330-99-8026322					
5330-99-8069180	*	*			
5330-99-8069181					
5330-99-8069183	*	*			
5330-99-8069184	*	*			
5330-99-8092982	*	*			
5330-99-8092984	*	*			
5330-99-8093763	*	*			
5330-99-8093764	*	*			
5330-99-8093770	*	*			
5330-99-8093989	*	*	*	*	*

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5330-99-8094221					
5330-99-8094230					
5330-99-9428455	*	*			
5330-99-9536360	*	*	*	*	*
5340-17-0367504	*	*	*	*	*
5350-NT-AA00965	*	*			
5350-00-1931340	*	*	*	*	*
5350-00-1931356	*	*			
5355-00-8144342	*	*			
5360-00-0979042	*	*			
5360-00-1153797					
5360-00-2917115	*	*			
5360-00-3147183	*	*			
5360-00-6643619	*	*			
5360-00-8089401	*	*			
5360-00-9131225	*	*	*	*	*
5360-01-0308490	*	*			
5360-01-0502947	*	*			
5360-17-0448144	*				
5360-99-5248278	*				
5360-99-5265478	*				
5360-99-5283858	*				
5360-99-5304158	*				
5360-99-5568870	*	*		*	
5360-99-7167889	*	*			
5365-00-4602615	*	*			
5365-12-1564463	*	*			
5365-12-1564466	*	*			
5530-NT-AA37721	*	*			
5610-17-0345784	*	*			
5640-00-2818627	*	*	*	*	*
5640-00-2818628	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
5920-NT-AA00470	*	*			
5920-NT-AA36632	*				
5920-NT-AA36637	*		*		
5920-NT-AA64359	*				
5920-00-2803537	*				
5920-00-2805038	*				
5920-00-2850901	*	*			
5920-00-8506091	*	*	*	*	*
5920-01-0126202	*	*			
5920-01-0640939	*	*			
5920-17-7092199	*	*			
5920-99-0590110	*	*	*	*	*
5920-99-0590112	*	*	*	*	*
5930-17-0368734	*	*			
5930-17-0375622	*	*			
5930-17-0476846	*	*			
5930-99-0510504	*	*			
5935-00-4109252	*	*			
5935-00-4663394	*	*			
5935-00-4905219	*				
5935-00-9765425	*	*			
5935-13-1107280	*				
5935-17-0426121	*				
5935-17-0503474	*				
5935-17-9003461	*				
5940-17-0431098	*				
5945-01-0424191	*	*	*		
5945-01-0572646	*	*			
5945-17-0499919	*	*			
5945-17-0499920					
5945-99-0123878	*	*		*	
5950-01-0124831		*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5640-99-7165674					
5805-99-5370864					
5815-14-3538033					
5820-00-8777148	*	*			
5820-99-5197009					
5820-99-5197010	*	*			
5820-99-5197013	*	*			
5820-99-5197016	*	*		*	
5820-99-5274456					
5820-99-5279526	*	*			
5820-99-5279527	*	*		*	
5820-99-5279528	*	*			
5820-99-5279531					
5820-99-5279534	*	*			
5820-99-5279538		*			
5820-99-5279541	*	*			
5820-99-5331762	*	*			
5820-99-5370827	*	*			
5820-99-5370830					
5820-99-5370839	*	*			
5820-99-5370842	*		*		
5830-12-1713817	*	*			
5840-01-1305128					
5840-17-0473974	*	*			
5840-17-0499453		*			
5845-21-8710056					
5905-00-1086922		*			
5905-00-2793525	*	*			
5910-00-4543980	*				
5915-00-7616884	*	*	*	*	*
5915-99-5279524	*				
5915-99-5279536	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5950-17-9051410	*	*	*		
5950-21-8518099	*	*			
5960-00-5446225	*	*			
5960-00-6360370		*			
5960-00-8366504	*	*		*	
5960-00-8693995	*	*			
5960-00-9354981	*		*		
5960-00-9382663					
5960-01-0480975	*	*			
5960-01-1134309	*	*			
5960-17-0354931	*	*			
5960-17-0441810		*			
5960-17-0476536	*	*	*		
5960-17-0477970	*	*			
5961-00-0592904	*	*			
5961-00-0805234					
5961-00-0808752	*	*			
5961-00-1104909					
5961-00-1166553	*	*			
5961-00-3918721	*	*			
5961-00-6155186	*	*	*		
5961-00-6868579		*			
5961-00-7554349	*	*			
5961-00-7860324	*	*			
5961-00-8508449	*	*			
5961-00-9253777	*	*			
5961-00-9318228	*	*	*		
5961-00-9350138	*	*			
5961-00-9411914	*	*		*	
5961-00-9491440	*	*			
5961-00-9576865	*				
5961-01-0672192	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
5965-12-15801716					
5965-12-1614398		*			
5965-17-0434125	*	*	*		
5970-00-6306647	*	*			
5970-00-8122969	*	*			
5970-00-8272519	*	*			
5970-00-9541622		*			
7975-NT-AA64141	*				
5977-01-0718626	*				
5977-01-1232817	*				
5977-14-3254754	*				
5977-14-3254755	*				
5999-01-0937214	*				
5999-17-0410465	*				
5999-17-0410467	*	*			
5999-17-0420861	*	*			
5999-17-0425638	*	*			
5999-17-0449191	*	*			
5999-17-0455895		*			
5999-17-0486199	*	*			
5999-17-0486200	*	*			
5999-17-0495525	*				
5999-17-0498707	*	*		*	
5999-17-0504978	*	*			
6105-01-0686534	*	*			
6110-00-0647227	*	*			
6130-00-3943419		*			
6130-00-3943421	*	*			
6130-01-0937163	*	*	*		
6135-00-1201010	*	*			
6135-00-1201020	*	*		*	
6135-00-1201030	*				

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
6140-12-1894960	*	*			
6145-NI-AA00277	*	*			
6145-NI-AA00675	*	*			
6145-00-5426092	*	*			
6145-00-9378197	*	*	*		
6145-00-9378573	*	*			
6145-17-0368118	*	*		*	
6210-00-0642998	*				
6210-17-0047380	*	*			
6240-00-1557808	*	*			
6240-00-1557836	*	*	*		
6240-00-9378573					
6240-00-1558706					
6240-00-7637144					
6240-00-9412696					
6240-12-1402915					
6240-12-1666279	*	*			
6240-17-0483220	*	*		*	
6240-17-0513340	*		*		
6250-00-2395962	*				
6300-NI-P188187	*				
6625-00-1857817	*				
6655-00-1622481	*				
6660-17-0250424	*				
6680-12-1707972	*				
6680-17-0270309	*				
6680-17-0349071	*	*		*	
6680-17-0439148	*		*		
6680-17-9008388	*	*			
6685-01-0365994	*	*			
6685-01-1659212	*	*			
6685-17-0417956	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMOS	USED BY ELLI	USED BY LIMOS	COMMON USED
6685-17-0460940	*	*			
6685-17-0475346					
6685-17-0476578	*	*	*		
6685-17-0504987	*	*			
6685-17-9023498	*	*	*		
6685-99-5251932					
6760-17-0490741	*	*			
6810-00-1844794	*	*			
6810-00-1844799	*	*			
6810-00-2811864	*	*			
6810-00-6640388					
6830-00-2649071	*	*			
6830-00-2904374	*	*	*		
6850-NT-AA58250	*	*			
6850-NT-AA58251	*	*			
6870-NT-P169649	*	*		*	
6872-NT-P187839					
7220-NT-AA53016	*	*			
7510-00-2666710	*	*			
7510-00-2666712	*	*	*		
7522-ZP-oo10002					
7530-NT-AA56276	*	*	*		
7530-NT-AA56277	*	*			
7530-NT-AA58306	*	*			
7530-NT-AA60265	*	*			
7530-NT-AA73719		*			
7530-00-2237966	*				
7530-00-2739704		*		*	
7610-NT-AA33981	*				
7610-NT-AA34012		*			
7610-NT-AA34019					
7610-NT-AA34022		*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
7610-NT-AA34170	*		*		
7610-NT-AA34532	*	*			
7610-NT-AA34723	*	*			
7610-NT-AA45869		*			
8010-NT-AA60817	*	*			
8010-00-2982296	*	*			
8010-17-0321603	*		*		
8010-17-0420649	*		*		
8010-17-0420653	*	*			
8010-17-0425138	*	*	*		
8030-00-2441293	*	*			*
8030-00-2460931		*			
8030-00-2460933	*	*			
8030-00-2472525	*	*			
8030-00-7534597	*				
8030-17-0368728	*	*			*
8030-17-9019293		*			
8030-17-AA84119	*		*		
8040-00-2259548	*	*			
8040-00-8339563	*	*			
8120-NT-AA71944		*			
8305-NT-AA00034	*	*			
8315-NT-AA58592	*	*			
8330-00-2558282	*		*		
8888-NT-P920865	*	*			*
9320-NT-AA55797	*	*			
9350-00-1536804	*	*			
9350-17-0443888	*	*			
9350-17-0448480	*	*			
9350-17-0449481	*				
9350-17-0448482		*			
9397-00-0200323	*	*			

CODE NUMBER	REQUESTED FROM F/G ELLI	REQUESTED FROM F/G LIMNOS	USED BY ELLI	USED BY LIMNOS	COMMON USED
9505-00-1890720	*	*			
9505-00-5962315	*				
9510-00-1890563	*				
9510-00-1890583		*		*	
9510-00-1999322	*	*			
9510-00-5962017	*	*			
9510-00-5962020	*				
9515-00-1533215	*	*	*		
9515-00-2044524		*			
9515-00-2306693	*	*		*	
9520-00-2774912	*	*			
9520-00-2775986	*				
9530-00-2286854	*	*			
9530-00-2325626		*			
Totals	684	585	104	107	56

APPENDIX B

COMPUTATION OF P FOR SELECTED ITEMS WHICH BELONG TO THE MAIN ENGINE

HNSN	82a	82b	83a	83b	84a	84b	85a	85b	86a	86b	USED	nm*	P
8880 51	1			1	4	1				1	8	720	0.011
8880 49					1						1	40	0.025
8880 61						1					1	40	0.025
8880 39						2					2	80	0.025
8880 59					1						1	40	0.025
8880 77								1			1	40	0.025
8880 56						1					1	40	0.025
8880 41					5			4			9	240	0.038
8880 54							2		1		3	80	0.038
8880 7			2	2							4	80	0.050
8880 79						1		1			2	40	0.050
8880 84							2	1	1		4	80	0.050
8880 10	3	4			3						10	160	0.063
8880 50	4		5	3	4	9	2	2	1		30	400	0.075
8880 67	1		1	1							3	40	0.075
8880 86	2	2	1	1							6	80	0.075
8880 20			2	2			2	1			7	80	0.088
8880 29					8	8	7	6			29	320	0.091
8880 35	1		2	2	1			2			8	80	0.100
8880 73						1	1		1	1	4	40	0.100
8880 55			1	1	1	1					4	40	0.100
8880 78		1			1				1	1	4	40	0.100
8880 32			4	3	3	3	2	3			18	160	0.113
8880 87					2	2	2	2		1	9	80	0.113
8880 27			2	2	2	2	2				10	80	0.125
8880 34	6	6	4	5	5	3		2			31	240	0.129
8880 44	4	3	2	1	5	1	4	3	3	2	27	200	0.135
8880 4	1	1			1	2	3	2		1	11	80	0.138
8880 91			1	1	1	1		1	1		6	40	0.150
8880 68				1	1	1	1		1	1	6	40	0.150
8880 3			3	3	3	3	3	3			18	120	0.150
8880 31			4	5	10	10	8	7	10	8	62	400	0.155
8880 9	34	18	29	41	21	39	42	19	34	44	321	2000	0.161
8880 12	20	20	18		18	18	16	18	20	20	168	800	0.210
8880 1	48	40	48	48	32	48	32	32	48	48	424	1920	0.221
8880 5	17	21	20	18	22	22	16	19	21	22	198	880	0.225

* nm represents the total number of parts in the overhauled ships which are subject to replacement and is equivalent to nm in equation (2).

APPENDIX C

COMPUTATION OF P FOR SELECTED ITEMS WHICH BELONG TO THE ELECTRIC MOTOR

HNSN	82a	82b	83a	83b	84a	84b	85a	85b	86a	86b	USED	nm*	P
8890 62	1	1									2	120	0.017
8890 18							1				1	30	0.033
8890 29						1					1	30	0.033
8890 50					1						1	30	0.033
8890 77			6	5		4	5	4	4	3	31	600	0.052
8890 58	2	2									4	60	0.067
8890 46			1	1							2	30	0.067
8890 30	1	1									2	30	0.067
8890 65	1	1									2	30	0.067
8890 4	3	2	5	2	2	4					18	240	0.075
8890 9			2	2					1		5	60	0.083
8890 11	2	3	2	1							8	90	0.089
8890 55	4	3					4	1			12	120	0.100
8890 10			1	1	2	2					6	60	0.100
8890 8	10	8	10	10							38	300	0.127
8890 42	1	1			1	1					4	30	0.133
8890 22							1	1	1	1	4	30	0.133
8890 51					1	1			1	1	4	30	0.133
8890 67	1	1	1	1	1	1	1	1	1		9	60	0.150
8890 3	19	16	4	9	8	11			12	14	93	600	0.155
8890 70	6	5	4	6	5	4	3	2	2	2	39	240	0.163
8890 13	6	5	4	5	3	6			6	4	39	240	0.163
8890 20	1	1	1		1	1					5	30	0.167
8890 1	1			1			1	1		1	5	30	0.167
8890 72	4	3	3	4	4	2	2	4	1	4	31	180	0.172
8890 48			6	5		4	5	4	4	3	31	180	0.172
8890 6	24	33	38	29	35	37	28	23	21	19	287	1170	0.245
8890 78	4	4	4	4	3	4			3	4	30	120	0.250
8890 14	1	1	1	1		1	1		1	1	8	30	0.267
8890 15			1	1	1	1	1	1	1	1	8	30	0.267
8890 1	1	1	1	1	1	1		1		1	8	30	0.267
8890 60	1	1	2	1	2	2	2	2	2	2	17	60	0.683
8890 53	25	25	20	7	21	22	25	25	25	25	220	750	0.293
8890 61	1	1	1	1	1	1	1	1		1	9	30	0.300
8890 34	1	1	1	1	1	1	1	1		1	9	30	0.300
8890 2	3	3	3	3	3	3	3	3	2	2	28	90	0.311
8890 27	2	2	2	2	2	2	2	2	2	2	20	60	0.333
8890 24	1	1	1	1	1	1	1	1	1	1	10	30	0.333
8890 66	2	2	1	1	2		2	2	2	2	16	30	0.533
8890 74	19	18	20	20	10	9	16	15	19	6	152	180	0.844
8890 68	7	6	8	6	6	5	7	8	5	5	63	90	0.700

* nm represents the total number of parts in the overhauled ships which are subject to replacement and is equivalent to nm in equation (2).

APPENDIX D

OPTIMAL R AND Y FOR SELECTED ITEMS WHICH BELONG TO THE MAIN ENGINE

HNSN	C	K	Ch	Cs	Cp	R	Y
8880 51	$18	9.0	$0.90	$27	$0.54	0.865	4
8880 49	59	4.0	2.95	89	1.77	0.742	0
8880 61	212	4.0	10.60	318	6.36	0.742	0
8880 39	2488	4.0	124.40	3732	74.64	0.742	0
8880 59	201	4.0	10.05	302	6.03	0.742	0
8880 77	68	4.0	3.40	102	2.04	0.742	0
8880 56	1821	4.0	91.05	2732	54.63	0.742	0
8880 41	642	2.7	32.10	963	19.26	0.662	7
8880 54	346	2.7	17.30	519	10.38	0.662	1
8880 7	573	2.0	28.65	860	17.19	0.594	2
8880 79	243	2.0	12.15	365	7.29	0.594	1
8880 84	843	2.0	42.15	1265	25.29	0.594	2
8880 10	291	1.6	14.55	437	8.73	0.541	9
8880 50	74	1.3	3.70	111	2.22	0.493	29
8880 67	184	1.3	9.20	276	5.52	0.492	2
8880 86	11	1.3	0.55	17	0.33	0.485	5
8880 20	56	1.1	2.80	84	1.68	0.454	6
8880 29	109	1.1	5.45	164	3.27	0.454	29
8880 35	1	1.0	0.05	2	0.03	0.359	8
8880 73	36	1.0	1.80	54	1.08	0.431	3
8880 55	155	1.0	7.75	233	4.65	0.431	3
8880 78	79	1.0	3.95	119	2.37	0.431	3
8880 32	234	0.9	11.70	351	7.02	0.407	18
8880 87	87	0.9	4.35	131	2.61	0.407	9
8880 27	48	0.8	2.40	72	1.44	0.383	10
8880 34	16	0.8	0.80	24	0.48	0.383	31
8880 44	71	0.7	3.55	107	2.13	0.353	28
8880 4	81	0.7	4.05	122	2.43	0.353	11
8880 91	96	0.7	4.80	144	2.88	0.353	6
8880 68	93	0.7	4.65	140	2.79	0.353	6
8880 3	314	0.7	15.70	471	9.42	0.355	18
8880 31	29	0.6	1.45	44	0.87	0.321	64
8880 9	10	0.6	0.50	15	0.30	0.324	330
8880 12	4	0.5	0.20	6	0.12	0.290	174
8880 1	8	0.4	0.40	12	0.24	0.253	436
8880 5	16	0.4	0.80	24	0.48	0.253	206

APPENDIX E

OPTIMAL R AND Y FOR SELECTED ITEMS WHICH BELONG TO THE ELECTRIC MOTOR

HNSN	C	K	Ch	Cs	Cp	R	Y
8890 62	$14	6.0	$0.70	$21	$0.420	0.811	0
8890 18	2	3.0	0.10	3	0.060	0.684	0
8890 29	104	3.0	5.20	156	3.120	0.684	0
8890 50	58	3.0	2.90	87	1.740	0.684	0
8890 77	9	1.9	0.45	14	0.270	0.573	29
8890 58	108	1.5	0.40	162	3.240	0.511	3
8890 46	25	1.5	1.25	38	0.750	0.527	1
8890 30	44	1.5	2.20	66	1.320	0.527	1
8890 65	62	1.5	3.10	93	1.860	0.527	1
8890 4	64	1.3	3.20	96	1.920	0.493	17
8890 9	34	1.2	1.70	51	1.020	0.474	4
8890 11	8	1.1	0.40	12	1.240	0.502	7
8890 55	24	1.0	1.20	36	0.720	0.432	11
8890 10	25	1.0	1.25	38	0.750	0.429	5
8890 8	92	0.8	4.60	138	2.760	0.383	39
8890 42	83	0.7	4.15	125	2.490	0.354	4
8890 22	40	0.7	2.00	60	1.200	0.355	4
8890 51	18	0.7	0.90	27	0.540	0.355	4
8890 67	36	0.7	1.80	54	1.080	0.355	9
8890 3	19	0.6	1.95	29	0.570	0.345	95
8890 70	74	0.6	3.70	111	2.220	0.324	41
8890 13	130	0.6	6.50	195	3.900	0.324	41
8890 20	51	0.6	2.55	77	1.530	0.322	5
8890 1	60	0.6	3.00	90	1.800	0.324	5
8890 72	6	0.6	0.30	9	0.180	0.324	32
8890 48	14	0.6	0.70	21	0.420	0.324	32
8890 6	12	0.4	0.60	18	0.360	0.253	296
8890 78	5	0.4	0.25	8	0.150	0.239	32
8890 14	408	0.3	20.40	612	12.240	0.211	9
8890 15	24	0.3	0.15	5	0.072	0.661	6
8890 1	200	0.3	10.00	300	6.000	0.211	9
8890 60	3	0.3	0.15	5	0.090	0.192	43
8890 53	26	0.3	1.30	39	0.780	0.211	230
8890 61	54	0.3	2.70	81	1.620	0.211	10
8890 34	11	0.3	0.55	17	0.330	0.206	10
8890 2	35	0.3	1.75	53	1.050	0.209	31
8890 27	6	0.3	0.30	9	0.180	0.211	22
8890 24	16	0.3	0.80	24	0.480	0.211	11
8890 66	201	0.1	10.05	302	6.030	0.112	18
8890 74	12	0.1	0.60	18	0.360	0.113	158
8890 68	57	0.1	2.85	86	1.710	0.112	67

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